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WHERE HAVE ALL THE PROTOTYPES GONE?

THE FAILURE OF THE PROTOTYPING INITIATIVES OF THE 1990S

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Preface

In the early 1990s, the Department of Defense (DOD) announced a new strategy which was to change the focus of defense acquisition. During the Cold War, large defense budgets supported costly weapons production programs to meet the Soviet threat. Now, in the absence of a Cold War threat and in the face of sharply reduced defense budgets, the DOD announced a new approach featuring prototype demonstrations, in which models of a potential weapon system would be tested to validate its design without necessarily moving to a production phase. These new prototyping programs were to produce technologies that would be put on the shelf and selectively brought to production if required. For those of us in the aircraft test community, this new emphasis was met with a mixture of enthusiasm and skepticism. The enthusiasm stemmed from the nature of designing and testing experimental aircraft. It is extremely demanding and rewarding work. All the long hours in meetings over design trades, test safety, and a host of other concerns, are worth it when the product makes its first successful flight. But many were rightly skeptical that a prototyping program could be successful if it did not go to production soon after a flight demonstration. Historically, the contractor's costs of producing a prototype have been recovered in a follow–on production run. How prototyping programs would be paid for without the promise of a follow–on production contract was a point of debate. An additional concern was how a prototyping program could maintain its manpower pool of engineering and manufacturing expertise if an indefinite period of time lapsed between the demonstration and production.

Alas, the anticipated new wave of aircraft prototypes was not to be. In fact, the general notion of prototyping as an acquisition reform tool soon disappeared. It was replaced by a more specific type of prototype called an advanced concept technology demonstrator (ACTD). An ACTD is a program, approved by the Joint Requirements Oversight Council and the unified commanders, that operationally tests an application of an advanced technology, and, if successful, directly fields the test articles or begins a formal procurement of the system. As defined by the DOD under Secretary William Perry, the ACTD process applies to relatively simple systems with low production numbers, such as unmanned aerial vehicles (UAVs) or one–of–a–kind command and control networks. It is an approach that avoids the lengthy formal acquisition process for these selected systems and thus brings technology from the laboratory to the field in a matter of two to four years as opposed to the 10 to 15 years it currently takes complex systems to be fielded.

This paper traces the evolution of the prototyping initiatives from the early ‘90s to the definition of the current–day ACTDs. It discusses why the early initiatives in prototyping were doomed to failure for large, complex systems, and how the successor to these initiatives, the ACTD approach, promises to address the post–Cold War environment. It also describes the future of prototyping for complex weapons systems. Finally, it discusses the difficult choices facing policy makers who must attempt to modernize our defense forces with reduced defense budgets and an acquisition system left unaffected by the worthy, but unrealistic goals of the prototyping initiatives.

This topic is of particular interest to me because of my involvement in aircraft prototyping. I have been privileged to participate in both successes and failures in my 9 years in flight test. I have had the opportunity to work with aerospace professionals who have spent their entire careers making drawing board designs reality and providing our nation with some of the best combat aircraft in the world. I wanted to know where all the prototypes have gone, and I have found them in the relatively obscure world of ACTDs.

My thanks to Lieutenant Colonel Mikael Beno for his guidance on this project as the faculty research advisor, and for asking the question, “whatever happened to prototypes?” I also offer great thanks to interlibrary loan personnel for helping me find a rare speech transcript and to the other librarians who so patiently assist befuddled Majors who have forgotten how to write research papers.

Abstract

In the early 1990s, the DOD cast prototyping in a new role as an acquisition reform measure. Although prototyping was already an accepted part of system acquisition, the initiatives of the early '90s advanced the notion of prototypes as a means of developing technology without the necessity of costly follow–on production. Prototype technology could be shelved and selectively produced, offering huge potential savings in defense dollars. Since the time of these proposals, however, the expected surge of prototyping efforts for large, complex systems, such as aircraft and tanks, has not materialized. In this report, the author traces the acquisition strategies found in the DOD's *Annual Report to the President and the Congress* from 1992 through 1996 to show the evolution of this new role for prototyping. The author finds that the early prototyping initiatives evolved to a specific kind of prototyping—Advanced Concept Technology Demonstrators (ACTDs). An ACTD operationally tests an advanced technology and, if successful, directly fields the test articles or begins formal procurement of the system. This process applies to relatively simple systems with low–rate production (1–10 units), such as unmanned aerial vehicles. Though ACTDs may prove successful for these simpler systems, the prototyping initiatives failed for large, complex systems, for several reasons detailed in this paper. The impact of this failure is that policy makers have an acquisition system little changed from the Cold War. However, with sharply reduced budgets, policy makers face difficult force modernization decisions. The author discusses four options.

Chapter 1

Introduction

In 1992, the Bush administration embarked on a new defense acquisition strategy designed to continue US technological dominance in an environment of dwindling defense budgets and a shrinking national defense industry. At the heart of this strategy was a new emphasis on government–supported research and development (R&D), featuring prototyping of new technologies.[1] Prototyping, which had long been an accepted institution in systems design, now assumed a new role as an acquisition reform measure. In this new role, prototyping was to provide demonstrations of advanced technologies, without the traditional, automatic progression to expensive production programs. Indeed, prototyping demonstrations were to receive budgetary emphasis at the expense of production–oriented modernization programs.[2] Technologies validated by prototyping would be inserted into existing weapons platforms, be directly brought to production, or be incorporated into a next generation prototype without going to production.[3] This new strategy, and the other prototyping initiatives that followed, promised quick fielding of new technologies within the limited fiscal resources of the post–Cold War defense budgets.

But the new strategy failed. It did not produce new prototype programs for the most visible and expensive acquisition programs—large, complex weapons systems such as aircraft and tanks. For instance, no combat aircraft prototypes were tested or entered into service since the Advanced Tactical Fighter (ATF) flyoff in 1991. Had the new strategy taken root, one could have expected, by this date, at least one new aircraft prototype demonstration program announced as a direct result of this new strategy. Also, the strategy has disappeared from the literature of acquisition reform since William Perry's landmark speech on acquisition reform in 1994.[4] The new prototyping strategy was specifically mentioned in the National Military Strategy (NMS) of 1992,[5] but all reference to it has been removed from the current NMS (1995). Ultimately, the strategy was replaced. A new prototyping strategy, focused on smaller, less complex systems, evolved. This follow–on strategy defined a new breed of prototype called the advanced concept technology demonstrator (ACTD).

However, ACTDs do not address the large, complex weapons systems that will be necessary to modernize the defense force structure in the coming decades. The failure of the prototyping initiatives to address these systems leaves policy makers with an acquisition system relatively unchanged from the Cold War. However, the defense budget has dropped sharply from Cold War levels. Now policy makers face the daunting task of modernizing defense forces without the large budgets of the past or the cost–effective development methods promised by the prototyping initiatives.

The purpose of this paper is to clarify why the prototyping strategies of the 1990s failed and to discuss the impact of this failure on defense acquisition. After an explanation of prototyping and its recent role in procurement and acquisition reform, the paper will present the evolution of the prototyping strategies, as they appeared in the Defense Department's *Annual Report to the President and the Congress* from 1992 through 1996.

This will be followed by a discussion of the weaknesses that led to their failure and a look to the future of the role of prototyping in defense acquisition. Finally, the paper will consider how the failure of the prototyping initiatives impacts currently planned force modernization programs. A summary chart of the prototyping strategies is in Appendix A.

Notes

[1]Dick Cheney, *Annual Report to the President and the Congress* (Washington, D.C.: Government Printing Office, February 1992), 25.

[2]Representative Les Aspin, Chairman House Armed Services Committee, *Tomorrow's Defense From Today's Industrial Base: Finding The Right Resource Strategy For A New Era*, (Washington, D.C.: House Armed Services Committee, February 12, 1992), 10.

[3]Cheney, *Annual Report* (1992), 25.

[4]William Perry, Secretary of Defense, "Acquisition Reform: A Mandate for Change," *Defense Issues* 9, no. 10 (Washington, D.C.: Department of Defense, 1994): 1–11.

[5]Chairman, Joint Chiefs of Staff, *National Military Strategy of the United States* (Washington, D.C.: Government Printing Office, January 1992), 25.

Chapter 2

The Promise of Prototyping

> *My years inside the Skunk Works…convinced me of the tremendous value of building prototypes. I am a true believer. The beauty of a prototype is that it can be evaluated and its uses clarified before costly investments for large numbers are made.*
>
> —Ben Rich

Prototyping is a proven and valuable tool in design and testing for a diverse spectrum of systems. This chapter defines prototyping and discusses the distinction between technology demonstrators and production prototypes. It then reviews some of the success stories of prototyping in its traditional risk reduction role and the recent history of prototyping in its role as an acquisition reform strategy. Finally, it discusses the two major prototyping strategies of the early '90s.

Prototypes Defined

Before beginning a discussion of prototypes in their role as an acquisition reform strategy, prototyping must be defined and two types of prototypes should be distinguished. A prototype is a model which precedes the manufacturing of a production system. A prototype may be a partial or full scale model of the production configuration, and, likewise, may be selectively or fully representative of the production system. Prototyping is the process of fabricating a prototype that reflects a system design or a selected portion of a system design. It is important to note that prototypes are used for all types of systems from computer programs to brassboard experiments for space systems. This paper mainly deals with aircraft systems, but prototyping is useful in any system that requires the demonstration of new technology as part of its system development. Although definitions of prototypes vary among sources, two basic types can be identified as having important and distinct roles in the acquisition process.[1] The first prototype is the *technology demonstrator*. A technology demonstrator is typically built during the demonstration and validation (Dem/Val) phase of a procurement, and its purposes are to prove a new technology or set of technologies and to demonstrate a basic approach for their implementation into a developmental system. The technology demonstrator allows the acquisition decision makers to determine if an approach to a system can be further developed in the engineering and manufacturing development (EMD) phase, which normally follows Dem/Val. *Have Blue* was the technology demonstrator for the F–117. It was partially production representative, being about 40 percent smaller than the follow–on production aircraft.[2] Technology demonstrators, in this general sense, will be referred to as *Dem/Val prototypes* throughout the rest of this paper to prevent confusion with the specific technology demonstrator concepts detailed in chapter 3. The *production prototype* is built during EMD to conduct developmental and initial operational testing. Production prototype aircraft are often called flight test aircraft. They are distinguished from less mature prototypes in that they are often built from the same tooling as the production articles, and they are, to a greater or lesser extent, production representative. The F–117 program originally produced five production prototypes for developmental testing, before it made production aircraft to be fielded.[3]

Prototyping: A Proven Technique

Prototyping is a time–honored technique with a history of successes. In the aircraft world, Lockheed's Skunk Works was legendary for its ability to prototype new technologies and make small production runs (about 50) of aircraft like the U–2, SR–71, and the F–117. The profitability of these programs, coupled with the technology breakthroughs they offered, provided dramatic evidence of the advantage of prototyping small lot aircraft procurements and provided inspiration for the prototyping initiatives of the early '90s.[4]

Other recent successes of prototyping were the highly publicized F–16/17 and A–9/10 flyoffs in the 1970s. These were flyoffs between Dem/Val prototypes of opposing contractors, and they demonstrated the use of competition in prototyping to achieve the best value. They helped to institutionalize prototypes as an effective method of competing designs before embarking on the costly EMD and production phases of a procurement.

The 1990s saw the Advanced Technology Fighter (ATF) flyoff between Lockheed's YF–22 and McDonnell Douglas's YF–23. These Dem/Val prototypes were part of an innovative strategy in which the contractors bore a significant share of the development cost of the prototype.[5] Although the prototyping strategy was successful in providing a competitive flyoff and promising new technology, it was not able to prevent a major schedule slip. As of this writing, some six years after completion of the flyoff competition, flight test has not begun on a production prototype of the F–22. This fact illustrates that even successful prototyping programs cannot always overcome the pitfalls of complex weapons procurements. It also demonstrates that full–scale prototypes with sophisticated, operationally representative avionics and weapons suites, such as the ATF, may not be able to provide the procurement schedule streamlining envisioned by the prototyping initiatives. This point will be revisited in chapter 4.

The Joint Surveillance Target Attack Radar System (JSTARS), successfully demonstrated the role of prototypes in fielding systems while they are still under development. JSTARS was a production prototype that was not yet finished with contractor developmental testing when it was introduced into Desert Storm.[6] The two JSTARS prototype aircraft performed admirably in the war, fueling optimism for the fielding of prototypes in combat contingencies to circumvent the lengthy acquisition cycle.[7]

Prototyping in Acquisition Reform

Prototyping in the 1970s

The history of aircraft development since World War II is replete with prototyping programs, but in the 1970s, prototyping gained recognition as a proposed solution for acquisition system ills. Largely as a reaction to cost overruns in the F–111 and C–5A programs, prototyping was identified as a way to compete designs and reduce technical risk before costly production runs pushed the price of fixing deficiencies to unaffordable levels.[8] To manage its new prototyping programs, the Air Force set up a prototyping office at Wright–Patterson AFB.[9] This office was charged with implementing a prototyping strategy laid out by former Deputy Secretary of Defense David Packard. This strategy included a cost–level cap for each program, a mandate for minimizing paperwork and manning, and maximum flexibility for the contractor, including a reduction in design specifications—goals that have echoed through acquisition reform initiatives to this day.[10]

Interestingly, a goal of Packard's strategy was to continue developing the technology necessary to compete with the Soviet Union "by the relatively low–cost prototyping approach."[11] The desire to keep costs low by prototyping would also be a recurring theme in the years to come. The most familiar program the prototyping office managed was the lightweight fighter, which became the F–16. Although the follow–on production program, yielded some disappointments in weight growth and performance shortfalls,[12] the success of the prototyping flyoff between the YF–16 and the YF–17 helped establish the impression of prototyping as a promising approach to acquisition.

The Packard Commission (1986)

In 1986, the Packard Commission, led by David Packard, issued an extensive report on improving the Department of Defense's (DOD's) management and organization. Much of the report dealt with improvements to the defense acquisition system, largely as a response to horror stories of overpriced spare parts. Although the public perception of the time was that cost overruns were due to corruption, the commission found that such overruns were more often due to inefficiencies resulting in high technical risk and cost and schedule growth.[13] Prototyping was a critical part of the commission's strategy.

For several reasons, the commission adopted the highly regarded practice of prototyping in its recommended strategy for defense acquisition reform. Prototyping was the way to realistically estimate the development, production, and operational costs of major weapons systems.[14] It was the preferred method for technical risk reduction, that is, the weighing of the risks and benefits of emerging technology before the expensive production phase of a program.[15] In the commission's view, an effective prototyping strategy offered a "competition of ideas and technologies"[16] between manufacturing contractors. Another advantage was that the prototyping phase could be conducted under special streamlined procurement practices to reduce costs.[17]

But the real innovation offered by the Packard Commission was the mandate to *operationally* test prototypes before going to production.

> The proper use of operational testing is critical to improving the operations performance of new weapons. We recommend that operational testing begin early in advanced development and continue through full–scale development, using prototype hardware. The first units that come off the limited–rate production line should be subjected to intensive operational testing and the systems should not enter high–rate production until the results from these tests are evaluated.[18]

The conclusions of the Packard Commission laid the foundation for much of the development of prototyping in its role as an acquisition strategy in the 1990s. Their proposals for streamlined management of systems in the prototyping stage and early operational testing of prototypes were critical elements of the innovative proposals that followed.

The Prototyping Initiatives of the Early '90s

Department of Defense Strategy of 1992

Prototyping gained a great deal of attention in the waning years of the Bush administration under Secretary of Defense Dick Cheney. Although discussion of a new defense acquisition strategy featuring prototyping had been going on for years, the new strategy was definitively unveiled in the DOD's *Annual Report to the President and the Congress* of February 1992.[19] This strategy proposed a shift of emphasis from production programs to reliance on prototypes to demonstrate and validate new concepts. The Comanche helicopter was one example offered as a demonstration of this shift from production to prototyping and testing.[20] Prototypes would be more thoroughly tested (although *operational* testing was not specified), and fewer would proceed to production.[21] One effect of this would be the "shelving" of technology.[22] A shelved technology is a design that does not go to production. If a decision to produce a shelved technology is made, the contractor has to recall the engineering and manufacturing expertise and equipment necessary to bring the design to production. This process of recalling manpower and equipment becomes more difficult as more time between the conclusion of the prototyping effort and the production decision elapses. Another emphasis in the Cheney plan was producibility. Prototypes were to actually demonstrate that the eventual production articles could be manufactured with advanced and cost–effective techniques.[23] Producibility had previously been ignored or limited to planning for the production phase. Finally, to reduce procurement timelines, subsystems or technology proven in prototype form were to be inserted into existing weapons platforms.[24]

Rollover–Plus

Responding to these innovations was Representative Les Aspin's "Rollover–Plus" proposal, which he articulated in a speech before the American Defense Preparedness Association in February of 1992.[25] In his speech, he criticized the administration's strategy for failing to address the need to maintain the defense industrial base.[26] A prototyping strategy alone would not provide the level of effort and funding necessary to sustain the industrial base. Aspin's strategy was a four–fold approach of finishing existing production runs, keeping the industrial base healthy with low–rate production contracts, silver bullet procurements to meet new threats quickly (e.g., the F–117), and an innovative prototyping concept called Rollover–Plus.[27]

> In essence, we mean a process of continuous prototyping and development of manufacturing technologies. But this process would differ significantly from the process traditionally used in prototyping defense systems in that we would not commit to quantity production at the outset of the development. Instead, a prototype would not be brought into full scale production until the resulting component or system met stringent criteria. Those criteria are A) the technology works, B) it is required by development of the threat, or C) represents a breakthrough that would alter battlefield operations. If the resulting prototype did not meet those criteria, however, we would "rollover" the new technologies and lessons learned from development into a further iteration of engineering, development, and prototyping.[28]

In addition to these elements, which he had proposed as early as 1990,[29] he added the need to demonstrate producibility and the requirement for *operational* test and evaluation (OT&E) of the prototype.[30] As mentioned above, the requirement for OT&E of prototypes was an important legacy of the Packard Commission. It was this explicitly specified OT&E requirement for prototypes that was the salient difference between Aspin's prototyping strategy and Cheney's.

In summary, prototyping is a time–tested engineering practice with a history of success stories. From the 1970s on, prototyping gained momentum as a method of risk reduction for both cost and technical aspects of major weapons procurements. Prototyping was seized upon by the acquisition community in the early '90s as a method of continuing technological advancement in an era of reduced defense budgets. How these prototyping initiatives would be implemented was cause for much speculation. Some in the defense community envisioned "squadrons of prototypes"[31] demonstrating new technology. However, the coming years would show that the enthusiasm for prototypes of large, complex weapons systems would slowly give way to a new concept tailored less to traditional weapons systems and more to the threats of the post–Cold War era. This concept was the advanced concept technology demonstrator.

Notes

[1]Bruce Auster, "Prototypes," *Air Force Magazine* 75, no. 8 (August 1992): 53.

[2]David J. Lynch, "How the Skunk Works Fielded Stealth," *Air Force Magazine* 75, no. 11 (November 1992): 25.

[3]Jay Miller, *Lockheed's Skunk Works: The First Fifty Years* (Arlington, Texas: Aerofax, Inc., 1993), 165.

[4]Aspin, *Tomorrow's Defense*, 19.

[5]Glenn W. Goodman, Jr., "ATF Balances Stealth, Supercruise, Agility, Avionics," *Armed Forces Journal International* 128, no. 11 (June 1991): 78.

[6]Dr. Charles D. Lloyd, "A Technology Success Story: Joint STARS and Operation DESERT STORM," *Air Power History* 38, no. 3 (Fall 1991): 32.

[7]Lloyd, 34.

[8]Judyth L. Twigg, "To Fly and Fight: Norms, Institutions, and Fighter Aircraft Procurement in the United States, Russia, and Japan," (PhD diss., Massachusetts Institute of Technology, September 1994), 173.

[9]"Flexibility Is Key to Managing Prototypes," *Aviation Week and Space Technology* 96, no. 26 (June 26, 1972): 98.

[10]Ibid., 98.

[11]Ibid., 98.

[12]Twigg, 579–580.

[13]President's Blue Ribbon Commission on Defense Management, *A Quest for Excellence: Final Report to the President by the President's Blue Ribbon Commission on Defense Management* (Washington, D.C.: Government Printing Office, June 1986), 44.

[14]Ibid., 55.

[15]Ibid., 56.

[16]Ibid., 56.

[17]Ibid., 55.

[18]Ibid., xxvi.

[19]Cheney, *Annual Report* (1992), 25.

[20]Ibid., 25.

[21]Ibid., 25.

[22]Aspin, *Tomorrow's Defense*, 16.

[23]Cheney, *Annual Report* (1992), 25.

[24]Ibid., 25.

[25]Aspin, *Tomorrow's Defense*, 15.

[26]Ibid., 10.

[27]Ibid., 15–19.

[28]Ibid., 15.

[29]Ibid., 12.

[30]Ibid., 17.

Notes

[31]Lt Col Alan T. Nacke, *Analysis of "Rollover–Plus" An Acquisition Strategy Undefined*, (Maxwell AFB, AL: Air War College, Air University, April 1994), 7.

Chapter 3

The Emergence of Advanced Concept Technology Demonstrators

> *The objective of the Science and Technology (S&T) program is to support military needs and to solve military problems, as well as to provide a sound basis for acquisition decisions. Rapid technology transition into the operational forces is crucial. For these reasons, a new aspect of the S&T program has been defined: Advanced Concept Technology Demonstrations.*
>
> —Defense Science and Technology Strategy, Sept 1994

This chapter discusses the emergence of the Advanced Concept Technology Demonstrator (ACTD) as a successor to the prototyping initiatives of the early '90s. It begins with a description of Secretary Cheney's Advanced Technology Demonstrations (ATD)—the transition concept between the earlier strategies and the ACTD program. It then describes the new ACTD program initiated by Secretary Les Aspin. Finally, it details the more mature ACTD concept of Secretary William Perry and how it acknowledged the failure of the prototyping initiatives to address large, complex systems.

Cheney's ATD

In the Bush administration's final DOD *Annual Report to the President and the Congress* in 1993, Secretary Cheney's prototyping initiative took a new form in the concept of advanced technology demonstrations (ATDs).[1] The ATD concept was an enhancement to the less mature prototyping strategy proposed a year earlier in that it articulated criteria for advancing an ATD to production, as Aspin's earlier Rollover–Plus proposal did. Another improvement was its requirement that the systems demonstrated be compatible with the "Base Force"—the Bush administration's proposed reductions in force structure to meet the post–Cold War threat within the limits of the post–Cold War defense budget.

> The third core element of the Science and Technology (S&T) strategy, the use of advanced technology demonstrations (ATDs), along with simulations and exercises, will provide the tools to help ensure the technology is ready, manufacturing processes are available, and operating concepts are understood before any formal development program is considered. Each ATD will be designed to demonstrate to acquisition decision makers that the technology is feasible, affordable, and compatible with the operational concepts and force structure envisioned for the Base Force.[2]

This concept was part of a larger S&T strategy aimed at involving war fighters in the technology development process, exploiting advances in information technology, and providing realistic demonstrations of weapons systems prior to committing funds.[3] This step in the evolution of the prototyping initiatives established a new level of maturity, especially in the linkage of the prototypes with the proposed force structure. It would, however, be left to a new administration to continue the transition from a generic prototyping strategy to one using fielded technology demonstrators.

Aspin's ACTD

With the change of administrations, the *Annual Report to the President and the Congress* of January 1994 was written by new Secretary of Defense, Les Aspin. It introduced the advanced concept technology demonstrator (ACTD) program.[4] Although the new administration yielded a new acronym, the idea had not changed dramatically from Secretary Cheney's ATDs. ACTDs were part of an overarching S&T strategy that reflected a post–Cold war shift from threat driven development to technology driven development.[5]

> The S&T program was once driven by the need to maintain superiority over an aggressive and technologically capable adversary. Today, the S&T program is structured to maintain America's technology leadership and military superiority while supporting its economic security. The goal of the S&T program is to ensure operational forces have the systems they need to maintain military superiority, to prevent technological surprises, and to exploit technology to provide affordable, producible systems. These goals can be best achieved by taking advantage of an integrated effort consisting of defense and civilian technology developments.[6]

The ACTD approach emphasized cooperation between the war fighting and S&T communities. Prototyping, in the ACTD concept, would provide the traditional role of technical and cost risk reduction, while also providing a vehicle for refining the operational concept—how the system would actually be used in conflict.

> Each ACTD is an integrating effort involving very substantial cooperation and participation between the operational user and the S&T community. The user provides the operational context and concept of operations and manages the operational aspects of the demonstration; the S&T community provides the advanced technology elements. Thus the emphasis in the ACTD is to address operational utility and operational cost effectiveness with minimal technical risk. The goal is to refine operational requirements and concept designs adequately to facilitate insertion of the new capability into the formal acquisition process with minimal delay and cost.[7]

Also, as a management measure, Aspin created the Deputy Undersecretary of Defense for Advanced Technology to effectively manage the ACTDs.[8]

Clearly, there is little difference between this concept and the earlier strategies, except for a new emphasis on the interactive refinement of operational requirements and system designs. Such interaction was intended to allow the user to modify the operational concept for the developing system to the real world limitations revealed in the demonstrations. The developers would be expected to modify the system design to accommodate the evolving operational concept. Historically, the user has not had such a hand in system design modifications during the demonstration phase of a development. This emphasis on evolving operational concepts and system design during the demonstration phase would carry forward to Secretary Perry's concept of ACTDs.

Finally, it is important to note that Secretary Aspin's ACTD concept was still broad in scope and promised much of what the earlier prototyping initiatives did. Aspin maintained that a prototyping strategy could produce new systems with advanced technology that would be economically produced and fielded more quickly than normal.

> New technology must be attainable through DOD's procurement process so that new systems are fielded with the latest technology available. This will be accomplished through prototyping, limited fabrication of advanced systems to determine producibility and operational effectiveness, and evolutionary development of and infusion of new capabilities in long–term stable production programs. As a result, the time needed to introduce new capabilities will decrease, excess contractor capacity will be minimized, and lean production processes will be encouraged.[9]

Shortly, however, these high expectations for the DOD procurement strategy were to be realigned in Secretary Perry's ACTD concept. The fact that the prototyping initiatives were not producing demonstrations leading to new major weapons systems would be acknowledged in Perry's formulation of the ACTD strategy. ACTDs were going to change their focus to a special class of systems that were small, relatively simple, and addressed war fighter priorities peculiar to the post–Cold War strategic environment.

Perry's ACTD

The concept of ACTDs was brought to a new level of maturity under Secretary of Defense William Perry in 1994. In the fall of that year, the *Defense Science and Technology Strategy* refined the ACTD.[10] A dominant theme of this strategy was the early involvement of war fighters, with an emphasis on allowing the user's operational concept to evolve with the system design during the early informal stage of weapon development.[11] Although these ideas had been advanced under previous initiatives, the new idea incorporated in this strategy was the *fielding* of the ACTDs after operational testing by the user.

> An important element of the ACTDs is that the user is left with a residual operational capability and the wherewithal to continue use. This provides the commander with a significant improvement in capability and the ability to continue to refine the doctrine and tactics to maximize the potential of new technologies.[12]

An important role of ACTDs, implicit in all the initiatives since the DOD strategy of 1992, was to be the rapid transition of laboratory technology directly to fielded systems.

> Technology moves fastest if it can move out of the laboratory to an already fielded system. When the opportunity arises, new, but mature, technology can be inserted as an upgrade to a system in service. Particularly amenable to direct transfer from the lab to an existing system are information and electronics technologies that can enhance capability with the replacement of computers, communications, and software.[13]

Perry's ACTDs were further refined in the *Annual Report to the President and the Congress* of 1995. Many of the concepts already laid out in the earlier *Defense Science and Technology Strategy* were retained; such as, early and significant involvement by the war fighters, refinement of operational concepts and requirements, fielding of the ACTD, and expeditious transition of laboratory technology to the field.[14] In addition, the *Report* also defined the following four selection criteria for a system to become an ACTD.[15]

1. Offers a potential solution to a military problem or introduces a significant new capability. The Joint Requirements Oversight Council (JROC) and the unified commanders must approve an ACTD.
2. Is relatively mature and contributes to solving the problem.
3. Has an executable program and management plan.
4. Is a two to four year program that can be supported for two years in the field.

The *Annual Report* of 1995 also prescribed outcomes for ACTDs. If unsuccessful, ACTDs were to be terminated or restructured. Upon the war fighter's recommendation, an ACTD could enter the formal acquisition process at an advanced milestone (EMD or production) or be directly fielded with minor modifications.[16]

The *Report* also specified the flexible role that ACTDs play in the acquisition cycle.

> The ACTD, however, can serve as a prerequisite in the acquisition process for new technological capabilities by providing both the developers and users with better up–front definition and understanding of new systems. In some instances, the ACTD approach may be able to replace or accelerate the early formal steps of the acquisition process. In other cases, the ACTD may in itself become an acquisition path for items required in only small numbers. Surveillance systems; command, control and communications systems; and special operations equipment are examples of technologies which are often required in only limited amounts and may be obtained through the ACTD approach.[17]

ACTDs were proposed as the prototype of choice for this limited class of systems described above. They were designed to allow the user and the S&T community to agree on operational doctrine and requirements before committing to a costly production program. They also were intended to provide a streamlined "front–end" to an acquisition process that has become time–consuming and costly. How ACTDs live up to these expectations remains to be seen.

This rigor in defining ACTDs also extended to what the concept *does not* include. In the following statement, Secretary Perry restricted ACTDs from directly addressing the most visible and expensive defense acquisition programs—large, complex weapons systems.

> It [the ACTD process] is not, however, considered or intended to be a substitute for the formal acquisition system required to introduce large, complex weapons systems such as ships, tanks, or aircraft. Nor is it intended to support acquisition of new systems such as vehicles or munitions, which may be procured in large numbers and over a number of years, and which do not involve substantial modification of operational concepts or procedures.[18]

In this statement was an implicit acknowledgment that the ACTD program could not address the fielding of large, complex weapons systems. The new focus of ACTDs on smaller, simpler systems was the inevitable outcome of the failure of previous prototyping strategies to produce new prototypes of large, complex weapons systems. The causes of this failure will be discussed in chapter 4.

As of January 1995, the following ACTDs were approved.[19]

1. Rapid Force Projection Initiative: Enhanced Fiber Optic Guided Missile.
2. High–Altitude Endurance Unmanned Air Vehicle.
3. Precision Signals Targeting.
4. Synthetic Theater of War 97.
5. Precision Strike to Counter Multiple Launch Rockets.
6. Medium–Altitude Endurance Unmanned Aerial Vehicle.
7. Cruise Missile Defense.
8. Joint Countermine.
9. Kinetic Energy Boost Phase Intercept, Phase I.
10. Advanced Joint Planning.

One can see that these systems are not what has been traditionally associated with prototypes. The only aircraft are unmanned aerial vehicles (UAVs)—small, unmanned aircraft made in limited numbers. The others are advanced weapons concepts to meet specific military problems or command and control innovations. They are small programs when compared to most aircraft, tank, or ship production efforts. For instance, the medium altitude UAV program produced the Predator UAV, of which only 10 were made and fielded.[20] Many of these programs cannot be compared to a traditional major weapon system program in terms of production numbers. For instance, the Synthetic Theater of War ACTD proposes to demonstrate a distributed war–game simulation capability.[21] Like some of the other ACTDs, this software–oriented product does not lend itself to comparison with a standard production program.

These ACTD programs are also relatively small in terms of cost. The budget commitment to the entire set of ACTDs in the above list is $3.1 billion for fiscal years (FYs) 1995–2001.[22] Almost one–third of this money is budgeted just for the medium and high altitude endurance UAVs for FY95–98.[23] The table on the next page shows, for FY95–98, how the combined research, development, test and evaluation (RDT&E) and procurement budgets for these ACTDs compare to large, complex modernization programs.

Table 1. Comparison of Cost for ACTDs and Large, Complex Weapons Systems

System	FY95	FY96	FY97	FY98	Total
	(Current Year Dollars in Millions)				
Endurance UAV ACTDs[a]	195.5	216.2	253.1	269.6	934.4
F–22	2,280.6	2,164.9	2,003.0	2,263.7	8,712.2
Joint Strike Fighter	183.6	193.2	581.8	876.8	1,835.4
Abrams (tank) Upgrade	320.4	535.5	611.3	683.9	2,151.1
New Attack Submarine	455.6	1,217.6	774.6	3,156.8	5,604.6

Source*:* William Perry, *Annual Report to the President and the Congress* (Washington, D.C.: US Government Printing Office, March 1996)

[a]Combines medium and high–altitude endurance UAV ACTDs.

Note that two of the most expensive ACTDs combined are significantly less costly than any of the major weapons modernization programs listed here. Also, note that these data provide a snapshot in time. This four year period is a major part of the life of the ACTD, but is a small part of the lengthy procurement cycle for the other systems. For instance, the Joint Strike Fighter is years away from the expensive EMD and production phases.

Below is a list of ACTDs approved for fiscal year 1996.[24]

1. Battlefield Awareness and Data Dissemination
2. Air Base/Port Biological Defense
3. Combat Identification
4. Combat Vehicle Survivability
5. Semi–Automated Imagery Processing
6. Counterproliferation
7. Navigation Warfare

8. Joint Logistics
9. Low Life–Cycle Cost, Medium Lift Helicopters
10. Miniature Air Launched Decoys

Again, it is apparent that ACTDs address issues that the early prototyping initiatives did not explicitly anticipate. This list contains few weapons systems. The approved ACTDs reflect a new post–Cold War emphasis on command, control, and communications (C^3), intelligence capabilities, and defensive systems. Earlier initiatives, such as Cheney's 1992 proposal, focused on improving the acquisition of complex weapons such as bombers, submarines, stealth aircraft, and helicopters.[25] The relative lack of large, complex weapons systems in the list of ACTDs above is a reflection of changes in the perceived military threat and the role of the acquisition system in meeting it.

In summary, the prototyping initiatives evolved into technology demonstrator programs starting with Secretary Cheney's ATD program in 1993. ATDs introduced the concept of requiring compatibility between the technology demonstrated and the force structures it was intended to augment. Secretary Aspin's ACTD program introduced the notion of evolving operations concepts interacting with systems design during the demonstration phase. Finally, Secretary Perry's ACTD concept eliminated large, complex systems from the scope of the prototyping initiatives, opting instead to focus on smaller, simpler systems attuned to the post–Cold War environment. This change of scope was the natural result of the failure of the earlier prototyping initiatives to produce visible results in major weapons systems arena. The causes of this failure is the subject of the next chapter.

Notes

[1]Dick Cheney, *Annual Report to the President and the Congress* (Washington, D.C.: Government Printing Office, January 1993), 115.

[2]Ibid., 115.

Notes

[3]Ibid., 37.

[4]Les Aspin, Secretary of Defense, *Annual Report to the President and the Congress* (Washington, D.C.: Government Printing Office, January 1994), 137.

[5]Aspin, *Tomorrow's Defense*, 17.

[6]Aspin, *Annual Report*, 136.

[7]Ibid., 137.

[8]Ibid., 137.

[9]Ibid., 106.

[10]Director, Defense Research and Engineering, *Defense Science and Technology Strategy* (Washington, D.C.: Government Printing Office, September 1994), 17.

[11]Ibid., 17.

[12]Ibid., 17.

[13]Ibid., 24.

[14]William J. Perry, Secretary of Defense, *Annual Report to the President and the Congress* (Washington, D.C.: Government Printing Office, February 1995), 108.

[15]Ibid., 108–109.

[16]Ibid., 109.

[17]Ibid., 110.

[18]Ibid., 109–110.

[19]William J. Perry, Secretary of Defense, *Annual Report to the President and the Congress* (Washington, D.C.: Government Printing Office, March 1996), 86.

[20]Philip J. Klass, "Military User to 'Try Before Buying,'" *Aviation Week and Space Technology* 140, no. 16 (April 19, 1994): 24.

[21]Ibid., 24.

[22]Perry, *Annual Report* (1996), 85.

[23]Ibid., 186.

[24]Ibid., 86.

[25]Cheney, *Annual Report* (1992), 25.

Chapter 4

The Failure of the Prototyping Initiatives

> *New technology cannot be put on a shelf. It must be used. And the desperate need is to try to find ways to drastically reduce costs that would allow new generations of aircraft to evolve within the parameters of extremely modest defense expenditures. That will be the great challenge facing the Pentagon and the defense industry in the years to come.*
>
> —Ben Rich

The question remains of why the prototyping initiatives failed to address large, complex weapons systems. This chapter discusses the answer to this question. It follows with a discussion of the weaknesses of the current ACTD concept.

Large, Complex Weapons Systems

The prototyping initiatives of the early ‘90s failed to yield results in the arena of large, complex weapons systems, because they attempted to solve too many problems at the same time. Although all the goals of the initiatives were valid, they, by their nature, could not all be accomplished, because they tended to work against each other. For instance the requirement for a prototype to be fully operational works against the goal of reducing cost and schedule in the prototyping phase. There were four major contributors to the failure of the prototyping initiatives that will be discussed in this section. First, the initiatives attempted to reduce the cost of producing technology by eliminating the necessary incentive of follow–on production. Second, the requirement for operational testing was too costly for complex weapons prototypes. Third, the producibility requirement was likewise too costly for the prototypes. Finally, the requirement to field the Dem/Val prototypes was expensive and could not produce enough units to be tactically relevant for many complex weapons systems.

The prototyping initiatives of the early '90s failed to acknowledge that the cost of maintaining the capability to produce major weapons systems is necessarily high. Historically, the expensive prototyping process was paid for by follow–on production runs, in which the contractor could reclaim developmental investments with profits in production and programmed depot maintenance contracts.[1] Prototyping alone cannot sustain the defense manufacturing base.[2] Even if the labor and material costs for fabricating a prototype are directly reimbursed, the costs involved in maintaining capital equipment and expertise in the design and manufacturing work force cannot be paid by an occasional short–term prototyping project. Not following a prototyping program with production, that is, making the prototypes pay for themselves, makes prototyping prohibitively expensive for a product that cannot be fielded in tactically relevant numbers.[3] Prototyping is typically done by small teams with soft tooling and does not support the large work force and capital investment tooling required to make large production runs.[4]

Moreover, the most innovative, streamlined prototyping practices, that helped inspire the prototyping initiatives of the early '90s, depend on the existence of a stable production base rich in capital equipment and available manpower. In a 1988 speech outlining the management practices used by the Skunk Works in conducting its famous prototyping programs, Ben Rich, then vice–president of the Skunk Works, acknowledged this reality.

> I'd also like to note that these rules are contingent upon the premise that a "Skunk Works" should be part of a larger organization, as we are at Lockheed. In today's business climate, I don't think a "Skunk Works" would be feasible if it couldn't rely on the resources of a larger entity. It needs a pool of facilities, tools and human beings who can be drawn upon for a particular project and then returned to the parent firm when the task is done.[5]

The policy makers responsible for the prototyping initiatives of the '90s made a major mistake. They assumed streamlined prototyping efforts could take place without the necessary backdrop of production facilities funded by less efficient follow–on production contracts. Although Representative Les Aspin recognized the need to maintain an industrial base in his 1992 speech,[6] his Rollover–Plus concept, like the other initiatives, proposed prototyping without going to production—an obvious contradiction.

The requirement for Dem/Val prototypes to be operationally tested was also unrealistic for major weapons systems. An advantage of a Dem/Val prototype is that it can reduce cost by not having to meet all the operational requirements of a fully production representative system. The Dem/Val prototype maximizes its ability to reduce technical risk by economizing on features that do not directly impact the demonstration of the new technology involved. By introducing full–scale operational requirements, the cost of the Dem/Val prototype rises and its value in reducing the risk of the advanced technology is marginalized. For instance, if *Have Blue* had been required to have a fully integrated avionics and weapons suite, its cost would have risen dramatically, and its ability to demonstrate new low observable technologies and radical aerodynamic and flight control integration would have been compromised in the name of operational testing. Instead, its design features and the operational testing conducted were limited to those aspects required to demonstrate its distinctive technological advances against adversary radar systems.[7]

The ATF Dem/Val prototypes were highly missionized, meaning they were designed with a significant mission capability, even supporting the avionics and weapons integration necessary to conduct air–to–air missile launches. The ATF demonstrators met the goal of supporting operational test objectives early in the program, following the prescriptions of the Packard Commission. But the follow–on F–22 production program has not achieved the schedule reduction benefits of prototyping that were anticipated by the Packard Commission and the prototyping initiatives of the early '90s. In time, the ATF may show that many of the aspects of the prototyping initiatives, such as operational testing of Dem/Val prototypes, are sound methods for reducing technical risk, but do not result in cost and schedule reduction for large, complex weapons systems.

Producibility is another requirement of the prototyping initiatives that made them unsuitable for major weapons systems. A true demonstration of producibility requires the use of the same tooling that will be used in production.[8] For aircraft systems, this is hard tooling—a capital investment that is expensive to build, store, and maintain. As mentioned previously, the cost for this investment is usually recovered over the course of a large production run; however, no such recovery can be made for one or two prototypes or a low–rate production run. Hard tooling requirements dramatically raise the cost of a prototype. This is why prototypes are typically hand–built or built with soft tooling.[9] Thus, the producibility requirement is unrealistic for a complex system Dem/Val prototype, because of the cost and schedule impacts.

Finally, the push to bring prototypes directly to the operator in the field is inappropriate for a large, complex weapons system. To be fielded, the prototype must be fully capable. This yields the same difficulties mentioned above for the operational testing requirement. Weapons capability is expensive to build into a prototype. It is expensive in terms of both cost and schedule to design, integrate, test, and gain the necessary operational certifications. As a result, a requirement for weapons stretches out the procurement of the prototype itself. Additionally, if the system is a combat aircraft, the small numbers of prototypes that can be built for a major weapons system are generally not tactically significant. For instance, fighter aircraft generally operate in packages of two to four with several backup aircraft. Programs generally cannot afford to build more than two Dem/Val prototypes demonstrators for such systems.

There are exceptions. JSTARS is an important and frequently cited counterexample to the objection to fielding prototypes. But it is important to note that JSTARS was not a Dem/Val but a production prototype,[10] and the interruption of its developmental testing impacted its program schedule.[11] This is not to say that the practice of introducing production prototypes into the field is a better acquisition reform strategy than fielding Dem/Val prototypes. A production prototype has already passed through most of the formal acquisition process, being a product of the EMD phase. Fielding production prototypes offers no cost benefit, because the production tooling costs have been paid, and the resulting schedule delay in developmental testing actually raises the cost of the program. For this reason, using JSTARS as a success story for fielding prototypes is misleading, because JSTARS enjoyed the benefits of being fielded late in the formal acquisition cycle.

ACTDs

Although ACTDs have not failed for the smaller, simpler programs they are designed to address, there are elements of the ACTD concept that could prove to be weaknesses. The interactive development of a program's operations concept with its system design can complicate the design process. Technologies produced by ACTD programs may not be affordably transferable to other systems. Areas of emphasis for the current ACTDs may not produce technology needed to support the modernization of large, complex weapons systems. Finally, the short scope of the ACTD programs makes them unlikely to produce technologies mature enough to be integrated onto complex weapons systems.

In an effort to involve war fighting users early in the developmental process, the ACTD concept allows the operational concept to evolve with the system design during Dem/Val OT&E. This raises a potential problem of lengthening the Dem/Val phase with repeated design changes mandated by the user. In the experience of the author, this repeated change of design during the testing phase is an expensive, undisciplined approach to system design. Moreover, when the design finally goes to EMD, more changes to the operational concept and, thus, the design may be made. This resulting effect is a longer and more expensive Dem/Val phase, with no guarantee of a correspondingly shorter or less costly EMD phase.

Technology from ACTDs may be too expensive to insert into other systems. Importing technology from an independent source, such as an ACTD, to a weapons system already in design impacts the cost and schedule of that weapon system. If the contractor of the integrating system is different than the contractor which developed the imported technology, the integrating contractor must learn how to incorporate the technology—another cost and schedule impact. If the imported technology must be retrofitted to a fielded system, there are redesign and retrofitting costs. Any benefit of incorporating an ACTD technology into a developing or existing weapon system must be weighed against these attendant costs. In an era of dwindling defense budgets, these fiscal hurdles will become more significant.

ACTDs are less likely to produce breakthrough technologies for large, complex weapons systems such as aircraft, ships, and tanks. As mentioned in Secretary Perry's *Annual Report*, ACTDs do not apply to large, complex systems.[12] Rather, they address a new defense climate in which the threats that technology must meet are fundamentally different than the Cold War threat. The following is a list of the five future joint war fighting capabilities identified by the Joint Requirements Oversight Council (JROC) as most needed by the US combatant commands.[13]

1. To maintain near perfect real–time knowledge of the enemy and communicate that to all forces in near real–time.
2. To engage regional forces promptly in decisive combat on a global basis.
3. To employ a range of capabilities more suitable to actions at the lower end of the full range of military operations to allow achievement of military objectives with minimum casualties and collateral damage.
4. To control the use of space.
5. To counter the threat of weapons of mass destruction and future ballistic and cruise missiles.

To address these priorities the DOD identified the following twelve technology areas for investment of research and development resources.[14]

1. Dominant Battlespace Knowledge
2. Combat Identification
3. Information Warfare and Security
4. Precision Force
5. Joint Theater Missile Defense
6. Electronic Warfare
7. Counterproliferation

8. Chemical and Biological Warfare Detection
9. Countermine
10. Military Operations in Urban Terrain
11. Real–Time Logistics Control
12. Joint Readiness

One can see from this list that several of these major emphasis areas for the S&T program are ACTDs or are closely related to ACTDs. Clearly, less emphasis in the weapons development arena is being placed on large, complex weapons systems and more emphasis has been placed on systems identified for ACTDs. The priorities for the DOD's S&T program, approved by the JROC, show the threats that most concern the unified commanders are those concerned with regional conflicts. Areas for research and development are weighed more heavily toward information systems, sensors, and defense against missiles and weapons of mass destruction than toward aerodynamics, propulsion, and areas more closely associated with the large, complex systems of the Cold War.

Finally, the scope of an ACTD is not long enough to produce mature technologies for insertion into complex weapons systems. A two year program allows enough time for a demonstration that leaves the user with a decision to accept or reject the system. Technology maturation requires a rollover approach on a long–term testbed or series of prototypes. A short ACTD effectually transfers technical risk reduction to the follow–on production program or to the next ACTD.

In summary, the prototyping initiatives failed to work for large, complex systems because they levied unrealistic, contradictory requirements on the Dem/Val prototypes that could not be satisfied at the same time. The ACTD program was subsequently redefined to focus on a class of systems with low production requirements and simpler designs. Nevertheless, the ACTD process still has potential weaknesses. The success of the ACTD programs is yet to be determined. In the wake of this failure of the prototyping initiatives, the US defense community faces the prospect of modernizing its forces with dwindling R&D and procurement budgets. The future it faces and the hard choices left for policy makers is the subject of the final chapter.

Notes

[1]Richanbach, Paul H., et al. *The Future of Military R&D: Towards a Flexible Acquisition Strategy,* (Alexandria, VA: Institute for Defense Analysis, July 1990), 14.

[2]Auster, 53.

[3]Nacke, 11.

[4]Nacke, 18–19.

[5]Ben R. Rich, "The Skunk Works Management Style. It's No Secret," *Vital Speeches of the Day* 55, no. 3 (November 15, 1988): 89.

[6]Aspin, "Tomorrow's Defense," 10.

[7]Ben R. Rich and Leo Janos, *Skunk Works* (Boston: Little, Brown and Company, 1994), 57–58, 60–61, 348.

[8]Auster, 53.

[9]Ibid., 53.

[10]"Key E–8 Review Set for August," *Aviation Week & Space Technology* 144, no. 8 (Feb 19, 1996), 46.

[11]Lloyd, 34.

[12]Perry, *Annual Report* (1995), 110.

[13]Perry, *Annual Report* (1996), 136.

[14]Ibid., 136–139.

Chapter 5

The Future of Prototyping

> *In the year 2054, the entire defense budget will purchase just one aircraft. This aircraft will have to be shared by the Air Force and the Navy 3 1/2 days each per week except for leap year, when it will be made available to the Marines for the extra day.*
>
> —Norman R. Augustine

What is the place of prototyping in a large, complex weapons systems if the initiatives of the early ‘90s have failed? Conventional prototyping will retain its traditional role of technical risk reduction in the early stages of the lengthy procurement cycle. This chapter will describe the future of the modernization programs for large, complex systems and the role of prototyping in supporting them. It will also discuss the difficult choices that face policy makers in light of the failure of the prototyping initiatives to relieve budget pressure on the development of new weapons systems.

Modernization of Large, Complex Weapons Systems

Prototyping will continue to be an important tool of cost and technical risk reduction in the acquisition of large, complex weapons systems. The failure of the prototyping initiatives does not invalidate the proven roles of prototyping in demonstrating new technologies, providing a basis for realistic developmental and operational costs, and identifying design changes before the expensive EMD and production phases of a program. The failure of the prototyping initiatives confirms the DOD acquisition community is conducting business as usual for major weapons systems procurement. In the current budgetary environment, business as usual is risky, as the weapons modernization effort is dependent on the success of fewer, more expensive advanced technology programs.

Business As Usual

DOD procurement of complex weapons systems is proceeding as usual, and prototyping is fulfilling its normal role of risk reduction. Combat aircraft modernization programs offer illustrations of this claim. Procurement of combat aircraft continues to be expensive and time consuming despite efforts to use prototyping to reverse these trends. Witness the example of the ATF. Prototyping fulfilled its traditional role of cost and technical risk reduction with two competing, highly missionized Dem/Val prototypes. However, regardless of the successful flyoff in 1990 and 1991, a production prototype of the F–22 is not scheduled to fly until May of 1997.[1] This time frame is consistent with the conventional 10 to 15 year developmental cycle (from concept initiation to production) for complex systems, rather than with the streamlined schedules anticipated by the prototyping initiatives. So, too, the Joint Strike Fighter (JSF) prototypes scheduled to fly late this decade are simply Dem/Val prototypes which will lead to a follow–on production contract.[2] In each case, these prototypes fulfill their historical role—cost and technical risk reduction. They do not offer the streamlined schedules foreseen by the prototyping initiatives. Also, as seen by the pending merger between Boeing and McDonnell Douglas after the JSF decision, they have done little to prevent what Rollover–Plus explicitly hoped to avert—the shrinkage of the defense industrial base.[3]

A Risky Future

"Business as usual" is risky business in an environment of dwindling defense budgets. Developing systems continue their trend of increasing cost and schedule. New systems programmed for force modernization are fewer and attempt to satisfy several roles formerly satisfied by different systems. The possibility of these expensive systems failing either technically or programmatically puts at risk DOD efforts to modernize the part of the force structure dependent on large, complex weapons. These trends are well illustrated by combat aircraft modernization programs.

Fewer systems will be required to meet the roles that many systems met in the past. In the table on the next page are the currently planned fighter aircraft modernization programs and the aging systems they are designed to replace.[4]

Table 2. Fighter Aircraft Modernization Programs

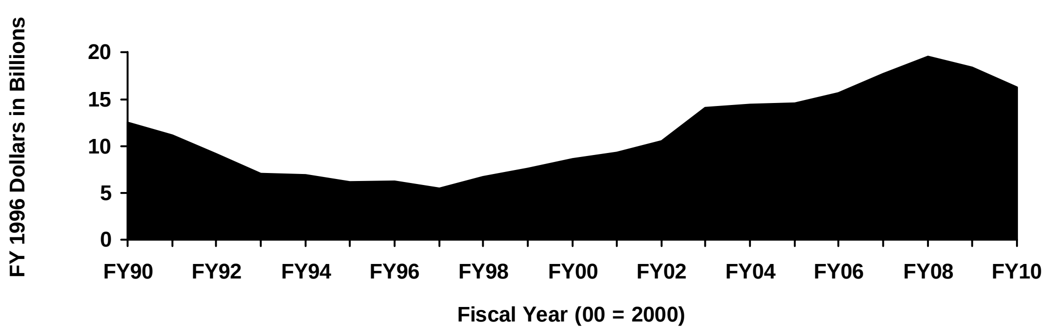
System	IOC[a]	System(s) Replaced	Roles of System(s) Replaced
F/A–18E/F	2001	A–6	Strike
F–22	2005	F–15C	Air Superiority
JSF[b]	2010	F–16	Multirole (Air–to–Air, Attack, Suppression of Enemy Air Defenses)
		F–14	Air–to–Air
		AV–8B	Close Air Support
		F/A–18A/C/D (USMC)	Multirole (Air–to–Air, Attack, Reconnaissance, Forward Air Control, Tactical Air Control System)
RIA[c]	2010+	F–15E	Deep Strike, Air Interdiction
		F–117A	Deep Strike

Source*:* William Perry, *Annual Report to the President and the Congress* (Washington, D.C.: US Government Printing Office, March 1996)

[a]Initial Operational Capability
[b]Joint Strike Fighter
[c]Replacement Interdiction Aircraft

Clearly, the highest risk for modernization is in the Joint Strike Fighter program. Were it to fail as the A–12 and A/F–X programs did earlier in the nineties,[5] several aircraft would have to continue in service and undergo upgrade and refurbishment programs.[6] But more alarming than the limited number of modernization programs, is the required increase in procurement budgets required to fund the modernization programs.

The cost for modernization of US forces will require dramatic increases in the R&D and procurement budgets. This concern is clearly evident from the proposed procurement funding for fighter and attack aircraft shown in the figure below.



Source: William Perry, *Annual Report to the President and the Congress* (Washington, D.C.: US Government Printing Office, March 1996): 180.

Figure 1. Procurement Funding for Tactical Aircraft Programs (FY 1990–2010)

The tactical aircraft programs in figure 1 include not only the replacement modernization programs shown in table 2, but also a number of upgrade and refurbishment programs, including those for the AV–8B, F–14, F–15, F–16, A–10, and F/A–18C/D.[7] To fulfill the currently planned modernization programs, just for fighter and attack aircraft, will require nearly quadrupling their procurement budget over the next 13 years. A four–fold increase in any part of the defense budget is unlikely in this time frame.

This cost risk is not limited to fighter and attack aircraft alone. Modernization programs, including both upgrades to existing equipment and new systems, are planned for bombers, cargo aircraft, submarines, destroyers, and tanks.[8] Total procurement costs for all modernization programs are slated to increase from $38.9 billion in FY 1997 to $60.1 billion in FY 2001—a 41 percent increase in real terms.[9] Secretary Perry's comments demonstrate the risk to modernization that this assumption of increased funding presents.

> For these DOD modernization programs to be fulfilled, the President's topline for FY 1998–2001 must be approved by Congress. The Department also must achieve its projected savings from infrastructure reductions…and from acquisition reform.
>
> Furthermore, it is critical that appropriated funds for procurement get allocated as planned in DOD's Future Years Defense Program. In other words, achieving the Department's modernization goals depends on Congress' supporting the specific spending allocation in DOD development and procurement plans and refraining from the diversion of funds to unrequested uses.[10]

The modernization of the forces of the future relies on a commitment of increased funding from Congress and success in realizing savings from acquisition reform. The likelihood of either producing the necessary increases in procurement funding is low.

The failure of the prototyping initiatives to truly reform procurement of large, complex weapons systems has left the US defense community with a procurement process much the same as it was during the Cold War. However, during the time of the prototyping initiatives, when it was hoped that new applications of prototyping would produce advanced technologies at reduced costs, the procurement budget sank to the lowest level in real terms since 1950.[11] Unrealistic requirements produced failure for the prototyping initiatives. In the same way, unrealistic expectations for the success of the prototyping initiatives allowed defense policy makers to let the procurement budget fall to low levels. Now it must increase by 41 percent, over the next four years, to meet even the short–term modernization goals. This risky modernization situation leaves the defense community and Congress with difficult choices.

Difficult Choices

There are four basic paths for senior–level decision makers to follow that address the force modernization problem. First, the DOD should consider changing its ACTD program to address needs of complex systems. Second, the DOD should relax its requirements for Dem/Val prototypes. Third, the DOD must accept a reduction in the numbers and total capability of complex systems in the post–Cold War force structure. Finally, Congress must arrest the trend of decreases in R&D and procurement budgets. Each option will be discussed in turn.

DOD should consider altering its ACTD program to service the needs of complex weapons systems. The ACTD program currently addresses a specific class of systems that do not include large, complex systems such as aircraft and tanks. However, if the ACTD program continues to prove successful, as it has for the Predator UAV,[12] it may become a useful tool for producing designs for complex system components such as aircraft engines, low observable materials, or avionics. Obviously, this would entail changing the nature of the ACTD program, and, therefore, may invalidate the very qualities that could make ACTDs successful, such as immediate fielding. Also, the limitations of the ACTD concept noted in chapter 4, such as difficulties in transferring technology to other systems, may prevent the success of this approach. This option should be considered over the next few years.

DOD should relax the requirements levied on Dem/Val prototypes. As a result of the Packard Commission, the Dem/Val phase for complex systems has become more rigorous in its operational testing requirements. The requirement for full–scale operational testing of a Dem/Val prototype raises the cost and extends the schedule of a program. This cost increase may be eliminated by a disciplined effort to limit the scope of the demonstration to those areas that make the program a distinct contribution to the advancement of technology. As mentioned before, the *Have Blue* program successfully limited its operational testing, and, hence, its costs, to what was required to demonstrate radar signature reduction—its unique technical contribution.

The defense community must accept the reduction in numbers of large, complex weapons systems and adjust its defense posture accordingly. This path is already being pursued and has the highest likelihood of being implemented. As mentioned in chapter 4, the JROC has already identified the lower end of the spectrum of military conflict as the focal area for military capabilities. The inevitable reduction in the number of attack and fighter aircraft, then, may be appropriate in light of the changing nature of the post–Cold War threat. What is important in exercising this option is making realistic assessments about what is required by the threat and what can be afforded by the taxpayer. Matching an affordable force structure to the global security environment will require great foresight.

Finally, Congress must arrest the trend of reductions in R&D and procurement budgets. It is this option that Secretary Perry's modernization plans are contingent upon.

However, in light of the lingering national debt and consistent reduction in the overall defense budget, this option is unlikely. What is more likely is the procurement budget will remain at its current level or continue to decline. In this case, the modernization programs are at risk. Policy makers will require great discernment as to which programs will be canceled or delayed. Ultimately, this will lead decision makers to the option of accepting reduced capabilities.

In summary, the failure of the prototyping initiatives for large, complex systems has left the defense community with business as usual. But in the environment of dwindling defense budgets, business as usual leaves policy makers with difficult choices. Most likely, the defense community will be forced to accept a lessened capability in large, complex weapons systems, due to flat or falling procurement budgets. Success in addressing the defense environment will be dependent on how well policy makers match their force structure decisions with the threat environment and the fiscal environment.

Notes

[1]Stanley W. Kandebo, “F–22 Test Plans on Schedule, First Flight on Track for May,” *Aviation Week and Space Technology* 146, no. 1 (January 6, 1997), 48.

[2]Edward J. Walsh, “The Need is Still There,” *Sea Power* 37, no. 6 (June 1994), 30.

[3]“Boeing Shifts Top Managers In Preparation for Merger,” *Aviation Week and Space Technology* 146, no. 3 (January 20, 1997), 28.

[4]Perry, *Annual Report* (1996), 180–182.

[5]Ibid., 181.

[6]Ibid., 183.

[7]Ibid., 181.

[8]Ibid., 175,196, 255.

[9]Ibid., 255.

[10]Ibid., 255.

[11]Ibid., 254.

[12]Gibson LeBoeuf, “Noel Longuemare on Acquisition Reform,” *Program Manager* 26, no. 1 (January–February 1997): 18.

Chapter 6

Conclusion

Fast. Good. Cheap…Pick two.

—Anonymous

The prototyping initiatives of the early ‘90s attempted to provide advanced technology at a cost consistent with steadily decreasing defense budgets. They failed because their authors unrealistically attempted to address diverse issues with a single approach. Prototyping was going to reduce the acquisition timeline by replacing the early part of the acquisition cycle with a streamlined Dem/Val phase, inserting successfully demonstrated technologies in existing systems, or directly fielding the prototype itself. Also, the prototypes were going to be cost effective, because they were not going to automatically progress to production. At the same time, the products were to present breakthroughs that met military needs. Not only would they be technologically advanced, but they would be operationally representative, allowing the user to conduct operational testing. Finally, they would demonstrate producibility by actually demonstrating new manufacturing techniques that would increase their eventual production efficiencies. The initiatives failed for large, complex systems because these goals worked against each other. It was unreasonable to expect streamlined costs and schedules for prototypes that were required to meet extensive operational and manufacturing requirements. It was also unreasonable to expect prototyping operations to survive without follow–on production contracts. The prototyping initiatives were succeeded by a new prototyping program called the Advanced Concept Technology Demonstrator (ACTD). ACTDs do not address large, complex weapons systems such as aircraft and tanks. Instead, they address smaller, simpler systems such as communications systems and unmanned aerial vehicles (UAV). The success of the ACTD program remains to be seen, although the Predator UAV is cited as a success.

The failure of the prototyping initiatives left the defense community with few meaningful changes to its procurement system. Procurement of large, complex weapons systems proceeds with its normal lengthy timelines and high costs. Prototyping continues to play its historical role of risk reduction. But business as usual is now more risky. Modernization efforts to replace aging complex systems rely on a few systems. The Joint Strike Fighter is an example of a program that replaces several aircraft fulfilling a wide array of roles. Also, in the years that the prototyping initiatives were promising advanced technology at lower cost, policy makers allowed the procurement budget to sink to the lowest levels (in real terms) since 1950. Now significant increases in the procurement budgets are required to meet modernization goals—increases that are unlikely to happen.

As a result of this high risk environment, policy makers are faced with difficult options. The author recommends the following four actions.

1. Change the ACTD program to address the modernization of complex systems. Use the successful aspects of this program to produce component technologies such as aircraft engines, low observable materials, or avionics.
2. Relax Dem/Val prototyping requirements. Reduce the scope of Dem/Val testing to the demonstration of technology that makes a unique contribution.

3. Accept a reduction in capabilities for large, complex systems. This will have to be done. The key to success is matching what the taxpayer can afford with what is really required by the strategic environment.
4. Arrest the trend of reductions in R&D and procurement budgets. This is the option chosen by Secretary Perry. However, it is unrealistic to assume the procurement budget can grow by the amounts required to fund the currently planned modernization programs. A realistic approach is a compromise between this action and action number 3.

The prototyping schemes of the early ‘90s could not produce capabilities for large, complex systems. As a result, the defense community is left to face the task of modernizing its force structure with a procurement system little changed from the Cold War. But the procurement budget has slipped to the lowest real levels since the beginning of the Cold War, and the currently planned modernization programs are at risk. How successful policy makers are in addressing the strategic environment depends on their discernment in matching real needs with actual resources. The prototyping initiatives failed to realistically assess the role of prototyping in system acquisition. Policy makers of the future will need to more effectively acknowledge the realities of cost and schedule for weapons systems and make the hard choices for force structure and budgeting.

Appendix A

Comparison of Prototyping Initiatives

Table 3. Comparison of Prototyping Initiatives

Prototyping Idea	Principal Tenets	Requirements for Systems
1970s	Competitive Flyoffs Cost level cap Streamlining Maximum contractor flexibility	None specified
Packard Commission	Realistic cost estimation Competition of ideas Technical risk reduction Streamlined procurement practices Operational test	None specified
Cheney—1992	Shift from production to prototyping “Thorough testing” Selective production decisions Producibility demonstrated Insertion into existing platforms	None specified
Rollover Plus	Multiple prototyping cycles to roll over technologies into later generations of prototypes Producibility demonstrated Operational testing required Early involvement of war fighters Part of larger plan including finishing existing production runs, low–rate production programs, and silver–bullet programs	Demonstrated to work Meets an emerging threat Offers technological breakthrough

Table 3–continued

Prototyping Idea	Principal Tenets	Requirements for Systems
ATD	Designed to demonstrate feasibility, affordability, compatibility with operations concepts and Base Force Conducted with simulations and exercises Part of larger strategy including early involvement of the war fighter and exploitation of information technology	Technology ready Manufacturing processes available Operating concepts understood
Aspin's ACTD	Early operational testing Early involvement of war fighters Technology driven development Technical risk reduction Interactive evolution of operational requirements and system design	None specified
Perry's ACTD	All tenets of Aspin's ACTD Fielding of developing systems Quick transition from laboratory to field Outcomes: Termination or restructuring Entry into procurement cycle Direct fielding	Offer potential solution to military problem OR introduce significant new capability—approved by JROC and unified commanders Relatively mature AND contribute to solving the problem Executable program and management plan Two to four year schedule with two years supportability in field

Glossary

ACTD	Advanced Concept Technology Demonstrator
ATF	Advanced Tactical Fighter
ATD	Advanced Technology Demonstration
DOD	Department of Defense
Dem/Val	Demonstration and Validation
EMD	Engineering and Manufacturing Development
JROC	Joint Requirements Oversight Council
JSTARS	Joint Surveillance Target Attack Radar System
NMS	National Military Strategy
R&D	Research and Development
RDT&E	Research, Development, Test and Evaluation
S&T	Science and Technology
UAV	Unmanned Aerial Vehicle

acquisition reform. A movement to reform the defense acquisition system with initiatives designed to reduce the cost and schedule of military procurements.

advanced concept technology demonstrator. A type of demonstration conducted early in the life of a potential system being developed for military use which features early involvement by the war fighter with the science and technology community, concurrent evolution of the operational doctrine for employment with system design, early operational testing, and possible fielding of the prototype system.

advanced technology demonstrations. A predecessor initiative to the ACTD. This prototyping initiative featured prototype demonstrations of new technology with a requirement for compatibility with the operational concepts and force structure of the Bush administration's Base Force.

demonstration and validation. The phase of the procurement cycle concerned with demonstrating that a system concept will work. Often during Dem/Val, a prototype will be tested to conduct the demonstration of its technical and programmatic merits.

Base Force. The Bush administration's notional force structure, reduced to meet the fiscal restraints of the post–Cold War era.

Dem/Val prototype. A kind of prototype built during the Dem/Val phase to prove new technologies that can be implemented into the basic approach for a developmental system. In this paper, this term is used in lieu of "technology demonstrator" when speaking of a technology demonstrator in the general sense in order to distinguish it from the very specific technology demonstrators featured in the prototyping initiatives; namely the ATDs and the ACTDs.

engineering and manufacturing development. The phase of the procurement cycle concerned with finalizing and testing the production design of a system.

flyoff. A competition between flying prototypes of a proposed weapon system. The most familiar flyoffs were between the A–9 and the A–10, the YF–16 and the YF–17, and the YF–22 and the YF–23.

hard tooling. Permanent heavy tooling for manufacturing of systems. Hard tooling is expensive because it is built for durability and to yield extremely tight manufacturing tolerances.

operational concept. The war fighter's conception of how a weapon will actually be used in combat.

prototype. A model which precedes the manufacturing of a production system. A prototype may be on a partial scale or full scale of the production configuration. Prototypes may be fully production representative or selectively representative of a production system. Some prototypes, called technology demonstrators, exist only to demonstrate the feasibility of a technology or system concept.

production prototype. A kind of prototype which is built during EMD to conduct developmental and initial operational testing. They are distinguished from less mature prototypes in that they are often built from the same tooling as the production articles and they are to greater or lesser extent production representative.

risk reduction. The process of using prototypes and other engineering design tools to test design options and reduce the risk of the ultimate design. Prototypes are particularly helpful in that they give the designers insight into how well the technology will work and how much it will cost to produce and maintain. With the results of prototype testing, designers can make changes to the production design that will increase the probability of success in achieving technical and programmatic goals. Technical risk reduction deals with improving the probability of meeting a system's performance goals. Cost risk reduction deals with improving the probability of meeting a program's cost limits.

Rollover–Plus. A prototyping initiative that envisioned several generations of prototyped technology being rolled over into the following generations before a production decision is made. Additionally, operational testing and producibility demonstrations were added to the basic prototyping requirements.

soft tooling. Temporary, cost–effective tooling typically used for prototype manufacturing. Soft tooling is made to produce only one or two systems and is usually discarded.

technology demonstrator. A kind of prototype which is typically built during the Dem/Val phase of a procurement with the purpose of proving new technologies that can be implemented into the basic approach for a developmental system.

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